

Frontal Sinus Fractures

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Abstract

Keywords

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- endoscopic treatment

The frontal bone serves a protective role, representing the transition between the facial skeleton and the cranium. Within its enclosure, the frontal sinus lies adjacent to many important intracranial structures, and injury to this region has severe complications if not properly managed. Historically, the goals of frontal sinus fracture management have been to best prevent intracranial complications with invasive procedures, but a recent shift favoring conservative management now aims to preserve the form and function of the frontal sinus and its outflow tract. With the advancement of endoscopic techniques and the development of new technologies, many alternatives to aggressive surgical management are available.

Anatomy and Development of the Frontal Sinus

The paranasal sinuses largely function as a protective cushion to the brain in the event of facial trauma.¹ The frontal sinus is the last of the paranasal sinuses to develop, evaginating from the frontal recess at the age of 2 and reaching adult size and form after adolescence. Alternative routes of development are possible, making the frontal sinus and its outflow tract structures of high anatomical variance.^{2,3}

The anterior wall, or table, of the frontal sinus is the strongest bone in the adult face, capable of withstanding 800 to 2,200 pounds of force. The more fragile posterior table serves primarily as a barrier to the dura mater and the brain's frontal lobe. The orbital roof and nasofrontal duct form the inferior boundary of the frontal sinus; however, a true duct is present in only 15% of the population, and this foramen is more accurately termed the *nasofrontal outflow tract*.

Epidemiology

Frontal sinus fractures represent 5 to 15% of all facial fractures and are most often the result of high velocity craniofacial trauma, such as motor vehicle collisions, assault, or falls. As such, concomitant intracranial or cervical spine injuries are common.^{1,2,4,5} These injuries are exceedingly rare in children due to their incompletely pneumatized

sinuses, small face-to-cranium ratios, elastic skeleton, and various social factors, including parental supervision.⁶

To best guide management, it is beneficial to characterize frontal sinus fractures as isolated anterior table fractures, combined anterior/posterior table fractures, and fractures with nasofrontal involvement.

Initial Assessment and Diagnosis

Physical Examination

Frontal sinus fractures should be suspected in all patients presenting with trauma to the upper face. The examination involves a thorough palpation of the supraorbital ridge, glabella, and soft tissue of the lower forehead. In the acute setting, swelling may obscure exam findings.^{7,8} Clinicians should pay special attention and note contour irregularities that remain as swelling resolves. Lacerations are often present in more extensive injuries and may suggest involvement of deeper structures.^{1,2}

Fractures involving the posterior wall and/or nasofrontal duct will likely present with depression of the supraorbital region, a loss of sensation in the distribution of the supraorbital nerves, and cerebrospinal fluid (CSF) rhinorrhea.⁹ Any nasal drainage is assumed to be CSF until proven otherwise by a cursory bedside "halo" test or β -2 transferrin laboratory analysis.^{1,2,10} Any patients presenting with a CSF leak or an

open fracture should be started on prophylactic antibiotics immediately.³

In the pediatric patient, frontal bone fractures are treated as cranial fractures. Frontal sinus fractures typically have more severe etiologies; hence, the initial assessment should focus on the stabilization of the patient.⁶ Information is often more difficult to gather in a pediatric exam; imaging results should be used to guide or focus examination.

Imaging

The gold standard in diagnosis and classification of frontal sinus fractures is a computed tomography (CT) scan of the face, head, and neck. Plain radiographs can be used to diagnose frontal sinus fractures, but do not sufficiently characterize the extent of fracture or detect nasofrontal involvement.^{7,11,12} Reconstruction of CT images in both axial and sagittal orientations is often helpful (►Figs. 1, 2). Clinicians should look for obstruction, complex anterior ethmoid cell fracture, or frontal sinus floor fracture as evidence of nasofrontal outflow tract injury.¹² Still, the function of the nasofrontal outflow tract is often difficult to assess with radiographic and clinical evidence alone. When present, CSF leaks may be localized by CT myelogram.¹⁰ Use of dye to evaluate the integrity of the transnasal passage is much less accurate, often underestimating the extent of injury.^{13,14}

Overview of Management

Management of frontal sinus fractures has rapidly evolved and seen a conservative shift over the past 30 years. Historically, motor vehicle accidents accounted for over 70% of frontal sinus fractures, but advances in vehicle safeguards over the past 30 years have decreased both the severity of injuries and the prevalence of motor vehicle associated fractures.^{5,15,16} The traditional guidelines on management of frontal sinus fractures were developed from studies that involved more critical injuries and lacked many newer technologies.⁵ Rohrich and Hollier reported that only 24% of their patients were conscious at presentation and



Fig. 1 Posterior table frontal sinus fracture.

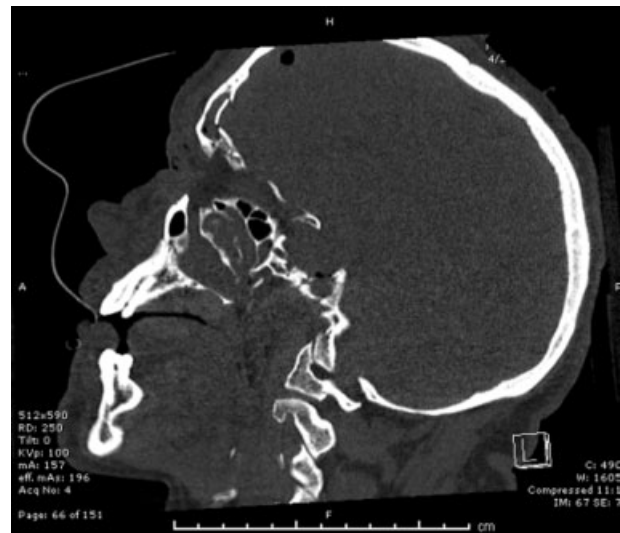


Fig. 2 Sagittal view of frontal sinus fracture.

those with an average Glasgow Coma Scale (GCS) score of < 8. 25 patients died within 2 weeks of surgery. In many cases, the posterior table was damaged beyond probable reconstruction and brain parenchyma was exposed.²

Current injury patterns show fewer fractures with posterior table involvement and an average GCS score > 12 at presentation. With less critical injuries, the management of frontal sinus fractures has seen a conservative shift. Treatment goals, previously focused on serious complication prevention, now place importance on the preservation of aesthetic form and function.¹

Current treatment options include strict observation, reconstruction of the fractured segments with duct and mucosal preservation, obliteration of the sinus cavity, and cranialization by removal of the posterior table and blockage of the nasofrontal outflow tract.^{2,12} When indicated, early surgical intervention has been shown to improve both cosmetic and functional outcomes by limiting the risk of skeletal distortion, scar contracture, and serious infection.¹⁷

There is much debate regarding indications for each management approach, and various algorithms exist to guide when observation versus surgical intervention is appropriate. One algorithm suggests operative intervention in a majority of frontal sinus fractures, particularly in the presence of persistent CSF leakage and nasofrontal outflow tract involvement,² while others argue that many complications are a product of invasive surgery.¹² More objective dislocation algorithms have also been presented.¹⁸

Surgical Techniques

Anterior Table

Isolated anterior table fractures are the most common presentation of frontal sinus fractures and carry the lowest risk of both early and late complications (►Figs. 3, 4). Minimally displaced fractures with only slight contour irregularity can be managed with cosmetic fillers and observation.^{1,5} Some isolated anterior table fractures, even in the case of

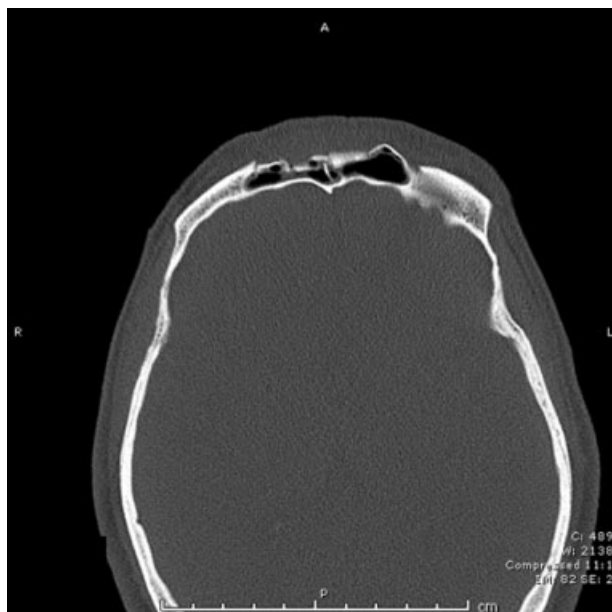


Fig. 3 Axial view of anterior table frontal sinus fracture.



Fig. 4 Sagittal view of anterior table frontal sinus fracture.

moderate contour deformity, may not require intervention in pediatric patients, as the frontal sinus is capable of further development.¹⁹

Minimally invasive endoscopic procedures are indicated in significantly displaced anterior table fractures with moderate contour irregularity. These procedures are performed under general anesthesia, as local anesthesia can make the area more difficult to see and handle alone.²⁰ The anterior sinus wall is accessed by a small hairline incision, or transnasal approach.⁹ Elevation and reduction of the fracture may then be accomplished by periosteal elevator and titanium screw placement, although Fattahi et al reported no need for fixation if the fractured segment is properly reduced to its anatomical location.²¹ The screw is removed after fixation and replaced with an absorbable plate. Endoscopic proce-

dures carry a significantly lower rate of complications, such as infection or paresthesia, and leave minimal scarring.^{20,22} Because full visualization of the fractured table is not possible, this method has a steep learning curve and requires a highly experienced surgeon.

Full surgical management by open reduction and internal fixation (ORIF) is indicated in severely displaced or comminuted fractures.¹ In many cases, surgeons may intraoperatively proceed with ORIF if the results of reconstruction using a minimally invasive approach are suboptimal.⁹ The procedure involves full visualization of the surgical field by hemicoronal or coronal incision, which has been associated with many complications including alopecia, paresthesias, temporal wasting, and prolonged recovery.^{5,21} Once the fracture is exposed by bicoronal flap, the sinus is carefully irrigated and the damaged mucosa excised. Stabilization or fixation of the fractured fragments of bone requires metallic or bioabsorbable microplates.^{2,5,8} Computed tomography image guidance may offer increased precision in extracranial repairs of the anterior table.²³

Posterior Table

Fractures involving the posterior table are almost always seen secondary to significant fracture of the stronger anterior table. They are also highly associated with additional intracranial injuries and the timeline of treatment is highly dictated by concomitant injuries and acute complications.⁵ A conservative watch-and-wait strategy, even in cases traditionally indicated for surgical intervention, has become the favored management plan; however, this approach relies heavily on close follow-up for years postinjury.¹⁵

Cranialization is the most aggressive and risky surgical procedure currently performed in the management of a frontal sinus fracture. It is only indicated for open, comminuted, combined anterior/posterior table fractures, where reconstruction of the posterior table is not feasible. Rohrich and Hollier's algorithm recommends the procedure for patients with a CSF leak persisting beyond 7 days, as these leaks will not likely spontaneously resolve and carry a large risk of intracranial infection.² The procedure involves removal of the entire posterior table and obliteration of the nasofrontal ducts, allowing the frontal lobe of the brain to expand into the space previously occupied by the frontal sinus. Complete burring of the sinus mucosa, obliteration of the nasofrontal outflow tract with a pericranial flap, and reconstruction of the cranial base are imperative.¹² This requires the hands of both a neurosurgeon and a plastic surgeon and significant time. Choi et al's 10-year study saw only 1 of 59 patients undergo cranialization, further exhibiting the field's conservative shift in posterior table fracture management.¹⁵

Nasofrontal Outflow Tract Involvement

Nasofrontal outflow tract involvement is assumed when fracture involves the ethmoids, medial superior orbital rim, or orbital roof and is seen in 25 to 50% of anterior table fractures.⁵ Clinicians can confirm injury with a fluorescein test.^{2,5} Previously the gold standard of management involved catheterization or stenting, but retrospective studies show

that 30% of patients fail to maintain a patent nasofrontal duct long term.^{2,5}

Standard practice currently involves obliteration of the nasofrontal duct and frontal sinus by spontaneous osteogenesis, bone, autologous fat, pericranial flap, or muscle (► **Figs. 5–7**).^{2,8,13,24,25} Spontaneous osteogenesis leaves no-risk donor-site morbidity, but autologous fat is the material most commonly employed.^{2,5} There is currently no true consensus on any superior method of obliteration.

Endoscopic techniques may also be utilized in nasofrontal duct repair when the clinician can ensure close follow-up.^{5,26} The procedure begins with the introduction of the endoscope through a coronal incision or pre-existing laceration followed by thorough antibiotic and normal saline irrigation.²⁷ The surgeon must then remove all mucosa from above the middle turbinate to the nasal roof with a microdebrider, create a septal window by clearing all bone and cartilage, and drill a connection between the frontal sinus and nasal cavity.¹ Any bone or mucosa that is left will stimulate fibrosis and spontaneous osteogenesis, narrowing the outflow tract and obliterating the sinus.²⁷ A majority of patients do appear



Fig. 5 Elevation of pericranial flap. Intraoperative photos (► **Fig. 5** courtesy of Salvatore C. Lettieri, MD, FACS. Division of Plastic Surgery, Mayo Clinic, Rochester, MN, and Plastic Surgery, Maricopa Integrated Health System, Phoenix, AZ.)



Fig. 6 Obliteration of frontal sinus and nasofrontal duct with bone graft after mucosal stripping. (► **Fig. 6** courtesy of Salvatore C. Lettieri, MD, FACS, Division of Plastic Surgery, Mayo Clinic, Rochester, MN, and Plastic Surgery, Maricopa Integrated Health System, Phoenix, AZ.)



Fig. 7 In-setting of pericranial flap. (► **Fig. 7** courtesy of Salvatore C. Lettieri, MD, FACS. Division of Plastic Surgery, Mayo Clinic, Rochester, MN, and Plastic Surgery, Maricopa Integrated Health System, Phoenix, AZ.)

to regain patency of the nasofrontal duct following endoscopic intervention, thus challenging previous ideas of obliteration as best practice.^{26,27}

Complications

The previous goals of treatment in the management of frontal sinus fractures concerned avoiding the many complications of injury. These complications are characterized as short term if they present within 6 months of treatment or long term if they present after 6 months of treatment. Short-term complications include sinusitis, persistent CSF leaks, and meningitis.¹ Long-term complications are typically more severe and may present as many as 25 years postinjury and treatment. For this reason, long-term follow-up is crucial to quality patient care.^{1,28}

Cosmetic deformities are common long-term unfavorable outcomes. Scars secondary to traumatic lacerations and contour irregularities secondary to repair may be managed

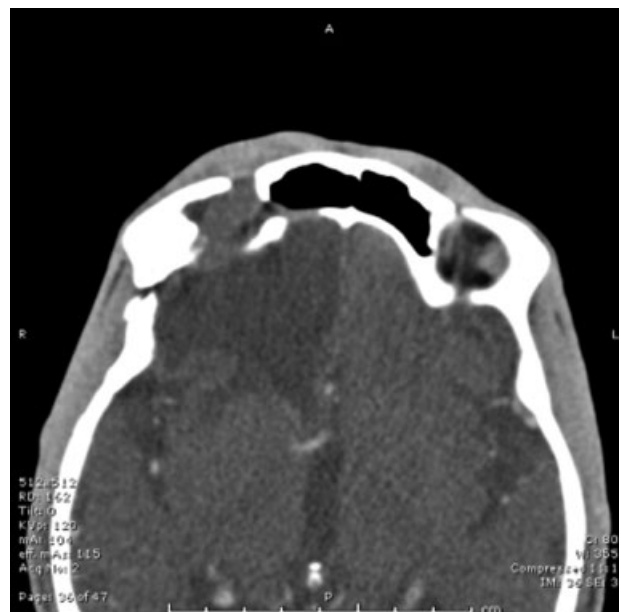


Fig. 8 Mucopyocele 10 years after initial injury and presenting with proptosis.

with injectable fillers or reoperation as needed.^{1,29} More life-threatening long-term complications include cavernous sinus thromboses, mucocoeles, mucopyoceles, and brain abscesses (► **Fig. 8**) To best avoid infection, extended postoperative antibiotics should be given to high-risk patients in accordance with current guidelines, and surgery should not be delayed beyond 48 to 72 hours when possible.^{17,30} Posterior table fractures are particularly subject to infection because they open a line of communication between the sinuses and intradural space.⁵ It should be noted that infections may present insidiously with mass-like symptoms or more gradually with sequelae of visual disturbances, bone resorption, overlying skin changes, or cutaneous fistulas.¹²

Conclusion

Management of frontal sinus fractures continues to evolve with the advancement of existing techniques and materials, development of new methods, and a changing patient profile. Although cranialization and other invasive operations were once the gold standard of care, close observation and endoscopic procedures are now often preferred. In either case, continual follow-up is imperative as complications often present many years after injury and treatment.

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